Projection of U.S. Coal-Fired Power Plants Potentially Impacted by Excess SO_3 Emissions

James T. Murphy
Science Applications International Corporation, 626 Cochrans Mill Road, Pittsburgh, PA 15236
E-mail: James.Murphy@sa.netl.doe.gov; Telephone: (412) 386-4115; Fax: (412) 386-4516

Summary

This presentation provides a projection of U.S. coal-fired power plants that potentially will be impacted by excess sulfur trioxide (SO_3) emissions and the resultant need for development of cost-effective technologies for control of SO_3 emissions. Fly ash and condensed SO_3 emissions are the major components in combustion flue gas that contribute to stack opacity. SO_3-related stack opacity problems will become more prevalent as additional coal-fired power plants are retrofit with pollution control equipment to meet future sulfur dioxide (SO_2) and nitrogen oxide (NOx) emission control requirements. It is estimated that 75 to 85% of bituminous coal-fired plants with selective catalytic reduction (SCR) and/or wet flue gas desulfurization (FGD) controls are likely to have sufficiently high levels of stack SO_3 emissions to experience excess stack opacity. Fortunately, subbituminous and lignite-fired plants are not expected to have the same problem as bituminous-fired plants.

The primary motivation for this assessment is a concern that recent stack opacity problems appear to be associated with coal-fired power plants that have been retrofit with SCR and/or wet FGD controls. Particulate matter (PM) emissions in the combustion flue gas from coal-fired power plants consist primarily of fly ash particles that are not captured by the particulate control device, wet FGD slurry carryover solids, and condensable sulfuric acid (H_2SO_4) aerosols. The H_2SO_4 is a product of the reaction of SO_3 and water that occurs as the flue gas cools across the air preheater. Plants burning medium to high sulfur coal that are equipped with wet FGD systems are particularly prone to experiencing stack opacity problems associated with the emission of H_2SO_4. The reason for this is that the gaseous H_2SO_4 is condensed to an aerosol mist entering the wet FGD system, but unlike SO_2, is not readily removed. Most reports indicate a maximum H_2SO_4 removal efficiency of 50% for wet FGD absorbers. Based on industry convention, the H_2SO_4 will be referenced as SO_3 throughout the remainder of this paper.

Stack SO_3 emissions from coal-fired power plants are extremely variable and can range from less than one ppm to over 30 ppm. While SO_3 emissions are not directly regulated, being a component of PM could result in their need for control to meet stack opacity limits. Whether a particular level of SO_3 emissions is considered a problem or not is dependent on numerous plant specific factors. Such factors as flue gas exit temperature; the particulate, NOx, and SO_2 pollution control equipment configuration and performance; stack diameter; and ambient weather conditions, can all influence the tolerable level of SO_3 emissions. The most notable example of excessive SO_3 aerosol emissions contributing to a stack opacity problem is American Electric Power's (AEP) Gavin Plant where the installation of a NOx SCR doubled the SO_3 emissions which resulted in a "blue plume".

The potential amount of existing coal-fired power plant capacity equipped with wet FGD that is most likely to experience SO_3-related stack plume opacity problems can be estimated based on fuel sulfur content and a few assumptions regarding the production and capture of SO_3 as the flue gas passes from the furnace to the stack. For this analysis, it was assumed that wet FGD plants with a stack SO_3 concentration greater than 5 ppm could experience stack plume opacity problems. A 5 ppm SO_3 upper limit may be a slightly conservative assumption. Stack diameter is also a major variable affecting opacity measurement and a small plant with corresponding small stack diameter could possibly tolerate a larger concentration of SO_3 without exceeding opacity limits. Cumulative distribution curves of coal sulfur content for plants equipped with wet FGD were used to project the percentage of affected wet FGD plant capacity with greater than 5 ppm stack SO_3 emissions. The SO_3 production and capture assumptions are as follows: 1) furnace conversion of SO_2 to SO_3 at 1%, 0.055%, and 0.1% for bituminous, subbituminous, and lignite respectively; 2) air preheater SO_3 capture at 20%; 3) electrostatic precipitator (ESP) SO_3 capture at 15%; and 4) wet FGD SO_3 capture at 15%. Based on this analysis, the average stack SO_3 concentration is 10 ppm for bituminous-fired plants with wet FGD and approximately 75% of these plants are estimated to exceed a 5 ppm stack SO_3 concentration compared to 0% for subbituminous and lignite plants.

A similar analysis was conducted assuming that all of the wet FGD coal-fired power plants are also retrofit with NOx SCR. The same assumptions are used as above for the wet FGD analysis, except there is an additional 1% conversion of SO_2 to SO_3 across the SCR catalyst for bituminous coal-fired plants. The impact of SCR-related SO_3 emissions for subbituminous and lignite plants is assumed to be negligible as a result of SO_3 adsorption by the alkaline fly ash. With the retrofit of NOx SCR, the estimated average stack SO_3 concentration increases to 19 ppm for bituminous-fired plants with wet FGD and approximately 85% of the plants are estimated to exceed a 5 ppm stack SO_3 concentration.

The use of FGD and SCR at coal-fired power plants will increase significantly over the next 15 years due to implementation of the U.S. Environmental Protection Agency's (EPA) Clean Air Interstate Rule (CAIR), which establishes a market-based allowance cap-and-trade program to permanently cap emissions of SO_2 and NOx in 28 eastern U.S states and the District of Columbia. The emission reductions will be implemented in two phases, with a Phase I compliance date of January 1, 2009 for NOx, January 1, 2010 for SO_2, and a Phase II compliance date of January 1, 2015 for both NOx and SO_2. To comply with the stringent SO_2 regulations proposed in CAIR, many coal-fired power plants will be required to install FGD technologies. EPA estimates that by year 2020 the total FGD capacity is projected to increase from the current 100 gigawatts (GW) to 231 GW. More importantly, the majority of this additional FGD capacity will likely use wet FGD technologies. In addition, EPA has estimated that a total of approximately 154 GW of SCR will have been installed on U.S. coal-fired power plants by 2020 for compliance with the NOx SIP call and CAIR. This dramatic increase in the use of wet FGD and SCR controls will further exacerbate the problem of excess SO_3 emissions in the future and requires the development of cost-effective technologies for control of SO_3 emissions.